BEST PRACTICES IN TRANSPORTATION MODELING FOR AIR QUALITY PLANNING

Prepared for The Environmental Defense Fund

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ABSTRACT

The 1990 Clean Air Act Amendments (CAA) require analysis of transportation programs for conformity with air quality implementation plans in regions that are in non-compliance with clean air standards. To examine conformity of transportation plans, Metropolitan Planning Organizations (MPOs) and other organizations generally need to rely on computer models that simulate the interaction between transportation and land use. Outputs from these models are in turn used with air pollution emission models to evaluate the impact of various policies and investments on air quality. The state of the practice in transportation modeling for air quality planning varies widely across the U.S., but there is general consensus among transportation professionals that current practices and capabilities for such analysis is weak and in need of substantial improvement.

The National Association of Regional Councils (NARC) and Environmental Protection Agency (EPA) have initiated efforts to define "Best Practices" in transportation modeling for air quality planning, to help guide agencies around the U.S. in transportation-air quality conformity analysis. NARC sponsored a conference on November 21-22, 1991, to discuss the topic of "Best Practices" with selected transportation professionals. For this conference, NARC commissioned a paper, "Toward Improved Regional Transportation Modeling Practice," by Greig Harvey and Elizabeth Deakin, to lay a framework for discussion. The Environmental Defense Fund is keenly interested in this issue and has prepared these comments to give guidance to metropolitan planning organizations, consultants, and policy-makers.

INTRODUCTION

The 1990 Clean Air Act Amendments (CAA) require analysis of transportation programs for conformity with air quality implementation plans in regions that are in non-compliance with clean air standards. To examine conformity of transportation plans, Metropolitan Planning Organizations (MPOs) and other organizations generally need to rely on computer models that simulate the interaction between transportation and land use. Outputs from these models are in turn used with air pollution emission models to evaluate the impact of various policies and investments on air quality.

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PREFERRED APPROACH TO SPECIFICATION OF "BEST PRACTICES"

The EDF believes that "Best Practices" for transportation modeling for air quality planning should be developed following several basic principles:

1. "Best Practices" should be performance-oriented, rather than process-oriented, to encourage innovation in modeling techniques. Performance standards should relate to the sensitivity of models and procedures to key factors and relationships between transportation, pricing, land use, and air quality (TPLUAQ), along with internal consistency in the treatment of data and appropriate validation of models. As part of "Best Practices," EPA/DOT should define validation procedures and criteria for TPLUAQ models used in conformity analysis.

2. Standards for "Best Practices" should be set at a high level, reflecting the "state-of-the-art," rather than at the lowest common denominator. "Best Practices" should acknowledge the need for some variance in standards of TPLUAQ model performance between regions at different levels of non-attainment of CAA standards. However, all regions required by the CAA or their implementation plans to implement TCMs or mandatory trip and VMT reduction should be held to the same highest standards. All fast growing areas in non-attainment should also be required to meet these standards.

3. Standards should not be static, but should be updated frequently to respond to rapid advances in computer modeling and transportation/pricing/land use/air quality analysis techniques and capabilities.

4. Recognition should be given to the poor state of the practice in many regions and the time required to improve transportation, pricing, land use, and air quality monitoring, analysis, and forecasting systems. Regions in non-compliance with the CAA that do not meet the "Best Practices" standards should be required to develop and adopt plans and schedules for improving these information and forecasting systems as rapidly as practically possible, as part of MPO Unified Work Programs and interim State Implementation Plan (SIP)/Transportation Improvement Program (TIP) conformity submissions to EPA/USDOT. Improved sensitivity to transportation pricing should be among the highest priorities for improved methods.

5. While improved systems are being developed, simpler techniques that provide policy sensitivity to key factors should be put to use as soon as possible for interim conformity analysis.

PERFORMANCE STANDARDS FOR POLICY-SENSITIVITY, CONSISTENCY, AND MODEL VALIDATION

"Best Practices" should leave room for innovation in techniques by devising performance standards related to appropriate policy sensitivity, internal consistency, and proper validation of TPLUAQ models. The "Manual of Best Practices" should generally avoid prescribing specific techniques for achieving such performance, although the range of current best practices for achievement of the performance standards should be discussed to provide useful information for practitioners and other interested parties.

Examples of performance standards for policy sensitivity, internal consistency, and validation that should be included in "Best Practices" are discussed separately below.

While there are a number of different approaches that can be taken to assess TPLUAQ relationships at a metropolitan level, with few exceptions, the classic four-step modeling process in use since the early 1960s remains the standard technique. The paper by Harvey and Deakin, "Toward Improved Regional Transportation Modeling Practice" identifies many of the shortcomings of this approach as applied by transportation agencies around the U.S. and many of the requirements for developing improved models.

Potentially superior alternate frameworks for TPLUAQ modeling should be explored and developed in the coming decade. Particular attention should be given to research and development work based on activity analysis, time-budget theory, and improved use of discrete choice analysis.

New techniques for refined spatial analysis, proximity planning, and representation of the pedestrian and cycling environment are emerging through the integration of Geographic Information Systems (GIS) with TPLUAQ planning and forecasting models. The number and share of jobs and houses within walking distance of transit and local services and the quality of the pedestrian environment together have a major influence on transit use and access mode choice, and likely influence trip generation, distribution, and the degree of trip chaining. Further research and model development is needed to document these relationships.

Recent advances in GIS technology provide a framework for low-cost data analysis of these disaggregate spatial relationships and can make conventional zone-based TPLUAQ models sensitive to such urban design factors. GIS can also provide a framework for development of more comprehensive inventories of parking supply, parking cost, and employer-based commuter subsidies. This is a vital area for increased data collection and analysis in most regions, as pricing factors have the greatest promise of all TCMs to induce short-term changes in travel demand.

SET "BEST PRACTICES" STANDARDS TO REFLECT THE STATE-OF-THE-ART

It is important to incorporate the highest state of the modeling art when identifying "Best Practices." The standards established generally should represent a combination of the best practices employed by various organizations involved in TPLUAQ analysis today. Without such an approach, it is likely that transportation-air quality conformity analysis will remain a meaningless exercise and will fail to identify effective strategies for meeting the goals of the CAA in many regions.

"Best Standards," if true to their name, can provide sound guidance to model development and applications by MPOs for conformity analysis and reduce the likelihood of litigation concerning issues of improper modeling procedures or inadequately documented assumptions.

A shortage of resources has hampered TPLUAQ data collection, analysis, and model development efforts even in the organizations employing the best work today in America. Thus, even the best current practices are unsatisfactory in providing some types of important and desired policy sensitivities. The "Manual of Best Practices" should identify areas where innovation in techniques and new types of data collection are needed to redress such deficiencies as quickly as possible.

"Best Practices" should acknowledge the need for some variance in standards of TPLUAQ model performance between regions at different levels of non-attainment of CAA standards. However, all regions required by the CAA to implement TCMs or mandatory trip and VMT reduction should be held to the same highest standards. Evaluation of TCMs and potential trip and VMT reduction measures require appropriate sensitivity to a range of policies, internal consistency in the treatment of data, and appropriate validation of models if conformity findings are to be found credible in a court of law. Regions that are in non-attainment and growing rapidly should also be required to meet the "Best Practices" standards, even if they are at a lower level of severity in their non-conformity. During periods of growth, regions have their easiest opportunity to shape their transportation, land use, and air quality, but tools are needed to assess impacts properly.

FREQUENTLY UPDATE "BEST PRACTICES"

Rapid innovation in TPLUAQ modeling and analysis is likely in the next decade, in response to increased funding for data collection and analysis, pressing transportation-air quality conformity deadlines and standards, and expanded attention to transportation demand management. Thus, "Best Practices" should be frequently reviewed and updated, at least every two or three years, to encompass important innovations in TPLUAQ modeling and analysis capabilities and to overcome deficiencies in the current best practices.

REQUIREMENTS FOR MODEL AND INFORMATION SYSTEM IMPROVEMENT

Current models in most regions do not meet acceptable standards and will require enhancement. This will be possible only by significantly increasing funding for TPLUAQ information and forecasting systems, which have been highly underfunded, especially in the past decade.

The significant increase in Federal support for MPOs and transportation planning activities under the 1991 Surface Transportation Act (STA) should facilitate this. Where this increase is insufficient to ensure sufficiently rapid progress in TPLUAQ analytic and monitoring capabilities, the STA's increased flexibility should enable the shifting of additional resources to support these activities.

The "Best Practices" should require each region that is in non-conformity with the CAA to prepare the following strategic elements as part of their SIP/conformity plan:

1. **Assessment of current TPLUAQ models and information systems** to identify areas needing improvement to adequately carry out CAA transportation/air quality conformity testing and to achieve the standards set by the "Best Practices".

2. **Development and adoption of a regularly updated five-year plan for TPLUAQ model and information systems development.** This should include —
    1. Identification of techniques that can be used in the near-term to provide policy sensitivities required by the "Best Practices," such as pivot point models and the use of qualitative indices to represent the effects of pedestrian and bicycle friendly vs. automobile oriented urban design, clustered mixed-use development within walking distance of transit nodes, parking pricing, commuter subsidy, and other policy changes, and the development of alternative land use growth scenarios consistent with automobile vs. transit oriented development patterns.
    2. Specification of new, more comprehensive TPLUAQ model structures that will be developed in the mid-term to provide enhanced policy sensitivity for CAA transportation/air quality conformity analysis.
    3. Identification of data collection and analysis activities needed to provide adequate support for TPLUAQ performance monitoring and model calibration/validation. This should include:

1. development of transportation pricing databases, reflecting the share of employees getting free parking at individual sites or within compact zones, the cost of short and long term commercial parking, HOV pricing incentives and other commuter subsidies, as well as transit costs on an origin-destination basis (if appropriate by mode),
2. initiation of household and employer-based panel surveys and other surveys to monitor changes in travel behavior and travel costs and subsidies over time,
3. development of regional traffic count inventories, with adequate peak hour, peak period, and 24-hour counts to support improved emissions inventories and TPLUAQ model calibration,
4. travel time and delay studies to provide the basis for improved calibration of emissions inventories and TPLUAQ models,
5. inventories of transportation supply, with information on road widths, number of lanes, presence of medians, intersection configurations, transit services, including transit stop locations and service frequency, parking inventories, including park-and-ride lots, location and character of sidewalks and bicycle paths and lanes, availability of secure bicycle parking spaces at transit stops, and other factors.
6. truck and goods movement data and surveys to support metropolitan goods movement strategy planning and emissions evaluation,
7. studies of special generators, such as airports and universities, to support their better consideration in the metropolitan TPLUAQ analysis process.
8. inventories of housing and employment location by type, including current land use, approved but unbuilt development, zoning ceilings, and forecasts in 5 year increments for more and less clustered or sprawled development patterns, dependent on transportation investment and policy and possible zoning changes,
9. development of historical inventories of changes in land use and transportation supply and price over recent decades to support development of land use forecasting models and the validation of long-range applications of TPLUAQ models.

3. **Preparation of a schedule and budget for this work**, to be adopted as part of the Unified Work Program of MPOs for regions in non-conformity, showing maximum effective progress towards achievement of the “Best Practices” standards.

REQUIREMENTS FOR MODEL SENSITIVITY

Accessibility. TPLUAQ models need to be made more sensitive to the impacts of changes in accessibility on travel behavior and location decisions. Accessibility is the key linkage between transportation and land use and has major influences on the entire travel demand analysis process. “Best Practices” should require:

- Internally consistent treatment of travel times in transportation models for destination choice, departure time choice, mode choice, and multi-modal network assignment should be part of “Best Practices”. This is already accomplished by several of the better metropolitan transportation models. This should be accomplished whenever possible through an equilibrium process, rather than through recursive iteration. In congested networks, recursion often does not provide satisfactory closure, exhibiting features of a chaotic system. Montgomery County, Maryland, has very recently developed an equilibrium destination and departure time choice/mode choice/network assignment algorithm implemented using EMME/2's equilibrium assignment process.

- Proximity of jobs and houses to each other and to public transportation and daily services should be better reflected in all stages of travel demand analysis. In many regions, this will require creation of new information systems to track jobs and households on a more disaggregate basis, using Geographic Information Systems (GIS). GIS can also enable the assembly of new databases on the location of transit stops, sidewalks, bicycle facilities, and other factors influencing pedestrian, bicycle, and transit friendliness.

  Current models are often unable to measure and analyze such basic questions as:

  - How many jobs and houses are within walking distance of bus stops and transit stations?
  - To what extent can workers or residents in this location accomplish their routine errands by foot?

  The large traffic zones that are common in many regional transportation planning models are poorly suited for proximity planning. New more disaggregate traffic analysis zone systems are needed in many regions. These should, in many cases, focus on transit nodes rather than being solely defined by major roads.

  Research in Montgomery County, Maryland, suggests that the frequency of trip chaining is related to whether people live and work in denser, more pedestrian friendly mixed use areas or in sprawled, more automobile friendly single use areas. While those in the former areas are able to accomplish more errands on foot at lunch time or after work, and are thus often less restrained from using transit for commuting, those in the latter areas are often made automobile-dependent by the need to run errands by car during the day. Proximity thus may have a significant impact on trip generation, distribution and mode choice.

  One of the greatest weaknesses in most current mode choice models is in the poor representation of transit mode of access. Adequately characterizing and simulating transit mode of access requires better information on proximity of jobs and houses to transit, the quality of the pedestrian and cyclist environment, and the cost and constraints related to automobile park-and-ride systems, as well as pedestrian and bicycle access to transit.

- Consideration of changes in accessibility on land development market forces. This can be accomplished in the short term by ensuring that alternative land use forecasts are prepared for air quality conformity analysis based on different transportation investment, operations, and policy scenarios. “Best Practices” should ensure that, as a minimum, land use forecasts vary with alternative transportation scenarios. Areas with expanded road or transit capacity should be evaluated for their potential for added growth due to improved accessibility.

This can be accomplished using linked land use-transportation models, such as ITLUP or POLIS, which require significant investment and data for calibration. Or it can be accomplished through more qualitative assessment, using Delphi techniques with local planners, land use experts, and citizens, taking into account past and anticipated trends and policies. Regardless of the process used, information is needed on recent and current land use patterns and change, the location of already approved development, the current zoning limitations, and potentials for redevelopment and zoning change, all on a small area (traffic zone) basis. Current accessibility patterns and potential changes under various transportation scenarios, including consideration of anticipated congestion, must become a significant factor in land use forecasting processes used to support transportation/air quality conformity.

Regions that fail in meeting conformity targets and need to implement trip and VMT reduction will be required to evaluate alternative transportation scenarios to those used in their earlier conformity analysis. These alternative scenarios should reflect changes in land use forecasts consistent with changes in transportation pricing, investments, and policy. Where significant transit investments are being evaluated, local land use and zoning policies should be evaluated for potential change to encourage more dense clustered development near transit nodes and downzoning in low-density automobile dependent areas. Where linked land use-transportation models are available, such potential changes in zoning should be evaluated for their potential synergistic interaction with changes in transit and highway accessibility and pricing.

- The Need to Consider Job/Housing Balance in Land Use and External Production/Attraction Forecasts. Conventional regional transportation models generate trip attractions and productions and normalize one to the other (usually forcing the number of employment attractions to equal the number of household productions for work trips, for example). At the same time, regional models require the specification of trip productions and attractions and through trips at the external boundary of the modeled region. It is important to ensure consistency over time in the treatment of these various sources of trip productions and attractions.

  In some regions, this normalization has hidden growing imbalances in the amount of forecast housing available for workers. This imbalance can be satisfied in only one of two ways -- by importing more workers into the modeled region from beyond the external boundaries for the region, or by assuming that some of the forecast employment is not realized. Normalization presumes the latter and that the unfilled jobs are proportionally distributed throughout the modeled region.

"Best Practices" should require an accounting for regional imbalances in job and housing growth over time in the specification of external productions and attractions, and an end to the practice of normalization of productions and attractions. Where such normalization factors are small, they are of little consequence, but where they grow over time, they may mask serious problems in the land use forecasts, unless explicitly compensated for by matched increases in forecast growth in external trip productions and attractions.

External trip productions and attractions should be sensitive to changes in land use and transportation forecasts. Improvements to roads, HOV facilities, or rail services that extend to near the edge or beyond the modeled region should be accounted for by appropriate changes to external trip productions and attractions at the affected external stations. Similarly, significant changes in forecast employment in areas near the edges of the modeled region should be accompanied by significant changes in external productions and attractions.

However, all of these problems of model consistency in treatment of job/housing interaction within and beyond the modeled region can be reduced by ensuring that the modeled region encompasses nearly all of the commuter-shed of the primary employment concentrations within the region of modeling interest.

Consistency of Land Use Forecasts with Investment Decisions and Pricing Policies. Conformity analysis should require a reasonable match between the assumed level of infrastructure investment, transportation pricing policies, fiscal capability to deliver the planned infrastructure, and the level and location of forecast growth. Large transportation infrastructure investments are generally not fiscally supportable without some degree of accompanying growth that makes use of these investments or significant user fees to finance costs.

"Best Practices" should not condone the use of fixed land use forecasts with widely varying transportation investment programs, as was the practice in the initial round of interim conformity analysis in 1991 and the MTC build/no-build alternative comparisons. More ambitious investment programs should be evaluated assuming a faster rate of growth in jobs and housing; no-build investment programs should be evaluated assuming a slower rate of growth. In other words, within limits, growth and investment should be coupled.

Significant changes in transportation pricing can also have some influence on growth patterns. Extensive subsidies for automobile use have contributed to growing trip lengths and sprawl over time; higher costs for single occupant vehicles (SOV) use combined with expanded non-SOV transportation options can be expected to favor more clustered growth and reduced average SOV trip lengths over time.

Precisely how these linkages can best be achieved and how specific transportation investments or pricing changes influence job and housing location is an area requiring further research and model development. However, in the short-term, Delphi approaches for modification of current land use forecasts to make them consistent with transportation scenarios should be the "Best Practice" approach, unless land use forecasting models are available in a region. The results of such work should be subject to a reasonableness test by the larger community. Even where land use forecasting models are available, the reasonableness of their sensitivity to changes in these input factors should be examined.

Sensitivity to Variations in Pedestrian and Bicycle Friendliness. There is wide variation in pedestrian and bicycle use across America, with some pedestrian and bicycle friendly communities showing walk and bicycle mode shares as high as 15 to 25 percent or more. In many new suburban communities and both new and old cities in much of northern Europe, walk and bike mode shares of 25 to 50 percent are common, for all trips and for access trips to public transportation. However, current transportation models in the U.S. usually lack proper representation of these modes of transportation, which have the greatest potential to affect the number of cold starts and hot soaks, and thus significantly reduce air pollution emissions.

"Best Practices" should require explicit representation of walk and bicycle modes in the travel demand analysis process, along with TCMs and infrastructure investment and management decisions that could increase the use of walking and cycling. This representation should take into account the potential for pedestrian and bicycle improvements to increase walk and bike mode shares, and the share of trips made by combining walking and cycling with public transportation.

There is a great need for basic data collection related to walking and cycling. In the near-term, bicycle and pedestrian friendliness may best be incorporated into current model structures using qualitative indices, as has been done for several years in Montgomery County, Maryland, with its "Transit Serviceability Index/Index of Pedestrian and Bicycle Friendliness." This approach gives a score to each traffic zone based on the extent and interconnectedness of sidewalks and bicycle facilities and traffic calmed or restricted areas, the density and mix of land use, the extent of building set-backs from the street, and the availability of bus stop shelters. Similar indices can be used as part of logit mode choice and other models as a surrogate for otherwise missing information on the character of the transportation supply system for pedestrians and cyclists. This approach could be used both in short-term pivot point analysis techniques and in more comprehensive regional models.

Research in the Washington, DC, region indicate that travel time and cost alone do not appear to be sufficient to explain variations in transit use. Pedestrian and bicycle friendliness appears to have a significant effect on how far people are willing to walk (or cycle) to reach public transportation. While few people will walk 10 minutes to a bus stop if that walk is along busy roads without sidewalks and where there is no bus stop shelter, more people will consider walking the same distance if there is a safe and comfortable place to walk, the opportunity to stop en route at shops to attend to errands, and shelter at the stop.

"Best Practices" should identify this area as one needing particular attention for research and development. There is significant promise for improved modeling methods to treat walk and bicycle transportation within the next several years. These will likely rely on GIS for inventories of sidewalks, street widths, traffic speeds and volumes, median strips and safety islands, locations of free right turns, bicycle paths and lanes, streetscape continuity, crime levels, and other factors influencing the friendliness of an area for walking and cycling.

Walk and bicycle transportation should be accounted for not only in mode choice but also in trip generation and distribution. It appears likely that when people are offered a high quality pedestrian and cycling environment and become reliant on these modes for a significant share of their travel, their destination choice, especially for non-work travel, is more strongly influenced by their pedestrian, bicycle, and transit accessibility than by their automobile accessibility.

These micro-scale factors can be measured for their influence on travel demand using GIS and disaggregate survey data. Pedestrian friendliness, for example, can be quantified by considering:

- ratio of sidewalk to street miles
- sidewalk connectivity
- share of length of main roads with sidewalks
- street crossing difficulty index (e.g. as a function of the traffic volume, speed, number of lanes without a median, frequency of pedestrian-signalized crossings)
- average sidewalk width
- share of sidewalks with buffers between sidewalk and street
- historic pedestrian accidents and fatalities
- proximity to pedestrian only streets
- incidence of street crime in neighborhoods

Bicycle friendliness can be quantified by considering factors such as:

- ratio of bikeway to street miles
- bikeway or bike lane connectivity
- share of length of main roads with bikeways/bikelanes
- street difficulty index (e.g. as a function of the traffic volume, speed, lane width, and pavement condition, aggregated for zones and for network connectivity estimation)
- intersection difficulty index (e.g. similar to index for pedestrians)

Automobile Ownership Sensitivity. Automobile ownership has been found in numerous studies to have a major effect on mode choice and trip-making. "Best Practices" should reflect a sound treatment of automobile ownership or availability as an important factor in travel demand estimation.

Moreover, "Best Practices" should include automobile ownership forecasting models that are sensitive to the potential for lagged negative effects of significant increases in transit, walk, and bicycle accessibility on household automobile ownership which is suggested by evidence from a number of communities. Further longitudinal and cross-sectional empirical research should be undertaken in a number of regions to develop automobile ownership models sensitive to such potentials, as well as to other policy and pricing factors that may influence automobile ownership.

Emissions models assumptions about motor vehicle fleet mix should incorporate sensitivity to changes in taxes and fees that are keyed to emissions or fuel use, such as the "feebates" proposed by a number of analysts, which would penalize purchasers or owners of high emission vehicles while rewarding purchasers or owners of low emission vehicles.

Departure Time Choice Representation. "Best Practices" should exclude the use of fixed factors for road links to convert simulated daily traffic volumes to peak or off-peak hour volumes. Instead, it is preferable to use explicit departure time choice models that factor trip tables, whether these are for daily trips or peak/off-peak trips.

While simple and easy to use, the fixed link factor approach, which remains common in practice, ignores important factors that can influence peaking characteristics, such as the level of traffic congestion in the corridor, peak period pricing, and the diversity of housing and employment at the trip origins and destinations. It appears very difficult to account for these factors with any type of link-specific peaking factors, making trip table factoring the currently preferred method for departure time choice estimation within the four-step process.

In general, when congestion delay in a corridor increases, travelers shift more of their trips to the shoulders of the peak. Fixed factors can overestimate peak hour congestion and delay by being insensitive to the elasticity in departure time choice.

Demographic heterogeneity in housing and employment appears to also have an effect on peaking. People traveling to and from higher-density mixed-use areas tend to spread their trips more across the 24 hours of the day than people traveling to and from relatively homogeneous campus-style suburban employment centers or new, automobile-oriented low-density suburban subdivisions.

Peak period pricing, in a variety of forms, can have a powerful effect on peaking behavior. The Dulles Toll Road, in Fairfax, Virginia, for example, is free for HOVs but a toll road for SOVs, and has induced changes in both automobile occupancy and departure time choice for automobile travelers in this corridor. Singapore's central area pricing system, which allows free entry into the CBD between 7 AM and 10 AM only for HOVs (of four or more persons) while charging a substantial fee for SOVs resulted in major mode and temporal shifts in travel behavior. Several cities in Sweden and Norway, including Stockholm, are now implementing area pricing with positive effects and represent this in their travel demand models.

These relationships can be represented by way of several different modeling approaches in the "four-step model," in what could be described as a "fifth step" -- departure time choice. Trip length, the ratio between free-flow and congested travel times for origin-destination pairs, and indicators of land use heterogeneity or density are key variables that should be considered in structuring departure time choice models, as in Montgomery County, Maryland. Where time-of-day pricing is a significant policy factor, it should be similarly introduced into model structures.

A typical current practice is to simulate trip generation and distribution on a daily basis and then factor to peak hour, using either link factors or trip table splitting factors. While departure time choice models can be validly applied to trip tables representing daily travel, there may be merit in doing trip generation and distribution by time of day.

By generating trips separately for AM or PM peak periods, base period, and evening, trip chaining can be far more easily represented, as this varies greatly by time of day.

Departure time choice models should represent the greater elasticity of non-work trips to shift to the shoulders of the peak or out of the peak completely, and the lesser elasticity of work trips, both linked and non-linked to shift away from the peak hour.

The use of time-of-day trip generation and distribution models can improve the estimation of trip length and directionality of flows on networks. While daily trip generation and distribution models can be manipulated to produce reasonable directional peak hour flows, directionality and trip character become far more obvious in the analysis of time-of-day trip generation/distribution models.

The conventional approach lumps together trips from home to work and work to home as “home-based-work-trips,” and must rely on attraction-to-production and production-to-attraction factors to account for directionality of flows at various times of day. Time-of-day trip generation/distribution models can produce estimates of AM and PM peak period home-to-work, work-to-home, and other trip purposes, both linked and unlinked. The trip distributions of these more discrete trip types by time-of-day vary widely. For example, home-to-work trips in the PM peak period tend to be shorter than home-to-work trips in the AM peak hour.

Sensitivity to Trip Chaining. In metropolitan areas across the U.S. over the past several decades, there has been a sharp decline in the share of work trips compared to non-work trips. However, much of this change can be attributed to growth in trip chaining. What were formerly trips directly from home to work have become trips from home to day care center to work, or work to shop to home.

Research in the Washington, DC region has shown that trip chaining is far more common among those living and working in the automobile-oriented suburbs than among those living or working in denser mixed use centers. Work trip length is also a factor. Those who make chained work trips overwhelmingly drive cars to make those trips.

“Best Practices” should be sensitive to the phenomena of trip chaining and its effects on trip generation, distribution, and mode choice. This may be accomplished within the “four-step” process by separately estimating linked and non-linked work trips by time of day, along with work-based and other non-home-based non-work trips, as has been done in Montgomery County, Maryland.

Integrating Multi-Modal Factors into Spatial and Temporal Trip Distribution. To ensure sensitivity to the full range of policy choices for long-term analysis of trip distribution, both spatial and temporal, a number of non-traditional factors should be considered for inclusion in the analytic process. Automobile and transit travel time and travel cost are key elements, but traveler choice appears to be influenced also by the quality of the pedestrian (and bicycle) environment.

To the extent that modes other than the automobile play or might play a significant role in travel for an area, including as transit access modes, consideration should be given to the travel time, cost, and "level of service" of these non-automobile modes in the travel demand analysis process. Choice-based logit models offer a suitable framework for statistical evaluation of significance of these factors, which include:

- travel time and cost by automobile, walk-to-transit, drive-to-transit, bicycle, and walk
- proximity of jobs and housing to transit (% within ¼ mile of bus stops and ½ mile of rail stations; % within 1½ miles of rail stations for potential bicycle access)
- proximity of jobs and housing to services (% within walking distance of shopping centers)
- household income
- household automobile ownership/availability
- automobile network density and quality factors (congested-to-freeflow travel time by auto, parking scarcity and auto egress time at destination)
- pedestrian network density and quality factors (e.g. the ratio of sidewalk miles to street miles, connectivity of pedestrian facilities, indices related to the difficulty of crossing streets, streetscape continuity and frontage factors, proximity to pedestrian-only streets)
- bicycle network density and quality factors (e.g. the ratio of bikeway miles to street miles, bicycle friendliness index of streets, bicycle parking availability/security factor, street crossing difficulty factor)
- number of jobs/households by zone (destination choice)
- congested-to-freeflow travel time by auto (departure time choice)

Level of Network and Zone Detail. The appropriate level of network detail in conventional transportation models is a function of the level of zone detail. Course zone systems with large zones are consistent with networks that represent only large roads. Fine-grain zone systems are consistent with networks that offer rich detail, including many small roads and transit lines.

Sensitivity to variations in proximity and accessibility of jobs and housing to each other and to public transportation requires finer grain zone systems than are typically used by MPOs. The current representation of newer, fast-growing suburban areas is typically most deficient, with the use of overly large zones. The use of large zones makes estimation of walk and bicycle travel potential highly problematic, given the short average trip lengths of these modes.

Representation of all streets that carry through traffic is important to representing network connectivity and alternative paths within networks, as well as developing regional inventories of mobile sources. Streets that carry public transportation similarly should be included in regional networks to permit proximity analysis of jobs and housing to transit, if possible, using inventories of transit stops maintained within a Geographic Information System (GIS).

Emissions analysis should consider also intrazonal trips. Reduction in the average size of traffic zones will reduce the number of intrazonal trips while making it possible to examine TCMs that divert some intrazonal trips from automobile to non-polluting modes, such as walk and bicycle.

"Best Practices" should include the explicit representation of intersection capacity and delay separate from link capacity and delay. A very large share of arterial vehicle delay is caused by intersections and turning movement conflicts, rather than by link capacity saturation. Montgomery County, Maryland, and other agencies have developed a method for explicitly separating these components of the highway network for equilibrium network assignment.
This may impose challenging requirements for larger databases and additional computer time for network assignments, especially in large regions. However, it can produce much more representative network loadings and representation of delay, acceleration/ deceleration cycles, and speeds, which are important for emissions analysis and forecasting. It may be expedient to develop surrogate representations of these factors in more aggregate network models for alternatives testing, but the development of more comprehensive base inventories and models that account for all these factors is important for improving emissions analysis.

Development of inventories of sidewalks, bicycle facilities, and streets with slow traffic speeds and low volumes friendly to cyclists and pedestrians is important to bringing these modes of transportation into the travel supply and demand analysis system. Without such inventories, TCMs intended to encourage cycling and walking cannot be properly prioritized for cost-effective transportation investments.

"Best Practices" should call for both finer grain zone and network databases to support TPLUAQ conformity analysis. GIS offers a low-cost means of managing and analyzing finer grain network and land use data. Zone and network detailing is most essential in areas where transit use is or may be expected to become significant and in major growth areas.

Census blocks and TIGER networks are a potential foundation for low-cost development of finer grain zone and network systems in any community in the U.S.. These can often be complemented by tax assessor parcel data bases and other pre-existing spatial data sources for major advances in capabilities for proximity planning, mode choice analysis, and policy-sensitive TPLUAQ modeling. Bus stop and sidewalk location data can be readily tracked using the TIGER file as a reference. Whatever the data structure used, be it TIGER or some other address referencing topological file, maintenance and updating of the files is important to ensure an effective planning tool.

Model Sensitivity to Changing Demographics and Urban Structure. "Best Practices" should ensure that travel demand models are sensitive to demographic changes, especially in trip generation. When new developments open, they often exhibit far different demographic characteristics than a decade or two later, as the population ages and increases in life-cycle diversity. The use of fixed trip generation rates that are assigned by area should be avoided.

Similarly, metropolitan structure changes over time. The multi-nucleation of metropolitan areas makes the use of "Central Business District" (CBD) binary variables increasingly suspect, as these variables typically mask variations in regional accessibility and pedestrian friendliness. CBD binary variables, however, are common, even among some of the most otherwise policy-sensitive travel demand models. CBD variables in models should be replaced by other factors relating to employment density, share of access to regional housing and employment, and pedestrian friendliness or other urban design factors. In this way, the effects captured by CBD binary variable can be reflected more explicitly and more incrementally in other emerging primary CBDs of multi-centered regions.

In general, trip generation models should be sensitive to changes in traditional factors, such as number of jobs and houses, but also to changes in --

- dwelling unit type
- household size
- building utilization factors (number of employees per square foot of space by type)
- labor force participation
- age distribution
- income
- automobile ownership/availability
- share of walk, bicycle, and transit trips (to determine extent of linked vs. unlinked trips)
- composite accessibility factors

Emission Model Sensitivity to Transportation Changes. "Best Practices" should require separate analysis of air pollution emissions related to Vehicle Miles of Travel (VMT running emissions), the number of trips (relating to cold start and hot soak emissions), and the number of motor vehicles (relating to diurnal emissions). The frequent practice of evaluating emissions as if they were related only to VMT by speed range is unacceptable and can lead to major errors in estimating the emissions impacts of TCMs.

For example, by switching longer automobile driver trips to park-and-ride, there may be a significant reduction in VMT but only a very small reduction in emissions, because the reduction in running emissions is small compared to the remaining cold start and hot soak emissions. On the other hand, by shifting short automobile trips to the bicycle or walking, there may be an insignificant reduction in VMT but a substantial reduction in emissions, through elimination of cold start and hot soak emissions.

"Best Practices" should facilitate more equal attention to running, trip, and diurnal emissions in the evaluation of TCMs by ensuring that models are sensitive to policies that can affect each of these components of automobile-related pollution sources.

At the same time, VMT-based emissions analysis should be sensitive to several factors not well accounted for in much initial conformity analysis work. These include --

- Many transportation models cap free-flow speeds on roads at the speed limit, even though real speeds often exceed the speed limit and enter a speed region where emission rates per VMT increase, rather than decrease with speed.
- Acceleration at intersections and highway ramps often account for very high emission rates for short periods of time, but are not accounted for by the average link speed approach used for emissions analysis.
- Traffic calming measures that slow down automobile traffic in residential or commercial areas can provide major improvement in the pedestrian and cyclist environment and reduce the number of trips (especially short trips) made by automobile. Conventional analysis approaches will reflect such changes as causing increased emissions due to lower average automobile speeds, but are insensitive to the reductions in high-emissions accelerations and cold starts/hot soaks that may be induced by traffic calming measures.

Representing Transportation Demand Management (TDM). TDM encompasses a very wide variety of transportation strategies, from pricing changes to marketing and encouragement programs and priority treatment of desired modes. Representing TDM in TPLUAQ modeling is a substantial challenge, given the complex details of many TDM programs, site specific application of programs, and the sensitivity of program effectiveness to the surrounding context in which it is implemented.

There are a variety of ways to attempt to represent TDM measures in the modeling process, but the most promising best practices to date have involved pivot point modeling, as is the approach of the COMSIS TDM evaluation software. For individual activity centers, this approach is quite useful. For entire metropolitan areas, it may be desirable in the mid-term to try to integrate the factors represented in such software into region-wide mode choice models. This would, however, often require additional data collection and revalidation or recalibration of mode choice models.

The COMSIS TDM model takes an approach that may be most helpful in providing required policy sensitivity in the short-term at low cost, while data collection and model development proceed towards creation of refined new TPLUAQ models for mid-term application.

At a regional level, the TRIPS model, developed from MTC data by Greg Harvey, offers a useful set of tools for adjusting regional models to better account for feedback of pricing and accessibility changes on trip generation, distribution, and mode choice. This disaggregate model is being used in the Los Angeles region by SCAG for evaluation of policy changes.

Many current regional models are insensitive to the income-related effects of major pricing policy changes. The TRIPS model provides a useful and potentially transferable framework for better incorporating these factors in regional conformity analysis in the short-term, using pivot point analysis methods.

The EDF believes that pricing is the most important tool for short-term management of transportation demand to meet air quality standards. One of the highest priorities of "Best Practices" should be to require sensitivity of travel demand models to transportation pricing changes, including parking charges, changes in commuter subsidies, tolls, area-pricing systems, transit pricing and fare instrument structures, and vehicle ownership and operation costs.

CONCLUSIONS

To meet the standards of the Clean Air Act Amendments of 1990, major improvements will be needed in the methods used to analyze the relationships between transportation, pricing, land use, and air quality (TPLUAQ) in metropolitan areas. Current methods for analysis of these relationships in most regions in non-compliance with the CAA are grossly inadequate to the requirements of that Act. Funding for TPLUAQ assessment, monitoring, and analysis must sharply increase in the immediate future.

A "Manual of Best Practices" is urgently needed to guide the efforts of local, metropolitan, and state agencies in this area. State-of-the-art methods are the lowest standard to which "Best Practices" should be established. Revisions in the "Best Practices" standards will be needed on a regular basis to reflect rapid advances in research and modeling techniques which are being driven by an urgent need to better capture the dynamics of travel behavior and their response to changes in pricing, urban design, transportation and land use policies, and infrastructure investment priorities.

"The Manual of Best Practices" should be an instrument to promote accelerated data collection and monitoring, model development, and analytic practice in communities across the U.S. which now fail to meet air quality standards. As it will take at least several years of increased funding and effort in this area to put into place appropriate analytic tools and information systems in most communities, parallel short-term efforts to enhance the policy sensitivity of existing tools will be essential to support interim transportation-air quality conformity analysis.